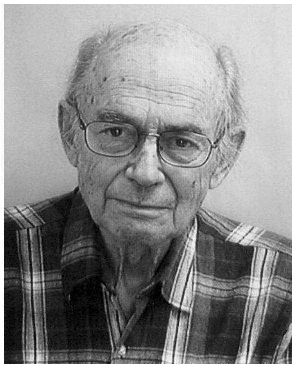
SIDNEY LOEB

Co-Inventor of Practical Reverse Osmosis



The most economical way to desalinate water is by Reverse Osmosis (RO). Prof. Reid from the University of Florida was the first to show that RO could produce potable water from saline solutions. RO is a membrane process driven by applied external pressure that is used to separate electrolytes from aqueous solution, among other applications. Sidney Loeb, together with Srinivasa Sourirajan, made it practical and possible. Worldwide production of RO water is estimated at 6.4 million m^3/d, and RO is the world leader in annual desalination plant installations.

Reverse Osmosis:

The RO desalination process is the application of hydrostatic pressure on seawater or brackish water surmounting a semi-permeable membrane. The membrane is "semi-permeable" in that it is permeable to water and almost impermeable to dissolved electrolytes. The water molecules pass through the membrane from the side of the higher concentrated solution to the side of lower concentrated solution. Little of the dissolved salts pass through the membrane. The initial solution is thus separated into two parts, one more concentrated in dissolved salts and the other almost pure water.

In RO the hydrostatic pressure must exceed the osmotic pressure of the saline solution. This process can be compared to what would take place with direct osmosis with the same membrane but without applied pressure, where the water would naturally migrate in the opposite direction, i.e., from the solution of lower to higher osmotic pressure.

Several theoretical models are used to describe solvent-solute transport in RO membranes, with the different models overlapping each other. The principal models for the transport process are known as "solution-diffusion" and "capillary pore". The active surface layer of the membrane forms hydrogen bonds with water molecules in the aqueous solution. By capillary action, the water molecules then move through the membrane. Solutes are rejected or absorbed by the membrane depending on the electrical charge of the solute molecule and by its ability to form a "solution" in the membrane. In RO, unlike in filtration, it is not membrane pore size and not dissolved particle size that determine the success of the separation process.

The principal advantage of RO over distillation is the saving of energy. RO involves no energy-consuming phase changes.

SIDNEY LOEB:

Sidney Loeb was born in Kansas City, Missouri in 1917 and from age two grew up in Chicago. He received his B.S. degree in chemical engineering from the University of Illinois in 1941. After working in the Los Angeles area in the fields of petrochemicals, rocket motors, and nuclear reactors, he returned to school and earned his M.S. (1959) and Ph.D. (1964) degrees from the University of California at Los Angeles (UCLA). It was during the course of his Master's thesis research that the Loeb-Sourirajan membrane breakthrough was achieved.

Major efforts were being made in the 1950's by the United States Department of the Interior through the Office of Saline Water, and by the State of California, to solve the growing problem of shortages of fresh water in dry areas. UCLA was heavily involved in the state supported desalination research.

Sidney Loeb recalls as follows:

The commercial utility of reverse osmosis depends on combining adequate permeate flux (permeate rate per unit membrane area) with acceptably low permeate salinity (usually less than 500 ppm). These were simultaneously achieved by us in late 1959 by the attainment of a membrane with a very thin (micron or *submicron) "skin" surmounting a relatively thick porous support layer. This anisotropic structure was verified by electronic microscopy at Gulf General Atomics in San Diego.*

In my opinion, such anisotropy is the seminal feature to the success of RO desalination, and has been a major contributor to the general surge of interest in and applications of membrane separation processes.

The attainment of anisotropy could be called serendipitous. However, "the road to success is paved with failures". The first test with an anisotropic (not known at the moment) membrane was close to being a success by the above two criteria. The second test (from the same membrane sheet) was a dismal failure with subsequent tests being equally good or very bad in random fashion, as if flipping a coin. From this we finally speculated that one side of the membrane was different from the other ***and that was it*** *(emphasis is that of Prof. Loeb). The side facing the air during casting on a glass plate had to be in contact with the saline solution during service.*

I sometimes wonder if I would have continued testing that membrane sheet if the first test had been a failure. The anisotropic principal is still valid today.

(S. Loeb, Membrane Quart. Oct. 1994 and 28 October 2001, personal communication).

Sidney Loeb and Israel

In 1967 Loeb came to Beersheva under the auspices of UNESCO to teach RO technology for a planned three months. This was by invitation of the Negev Institute for Arid Zone Research, later incorporated into the Institutes for Applied Research of the Ben-Gurion University of the Negev (BGU). At that time, work was being carried out on desalination by electrodialysis. Loeb stayed in Beersheva three years, left, and then made aliya, accepting a half time teaching and half time research position as Professor of Chemical Engineering at the newly established BGU. For 15 years at BGU Loeb carried out research and taught membrane processes, desalination, and other subjects, and retired in 1986.

Loeb recalls the work on the first RO plant in Israel at Kibbutz Yotvata, with the manufacture of the membranes at the Negev Institute. The women of the kibbutz immediately found good use of the soft RO water for washing their hair, but the kibbutzniks refused to drink RO water until Dr. Berlyne from the Soroka Medical Center spoke with them and warned of serious health consequences if they continued to drink brackish ground water. He scared the hell out of them. Loeb also remembers making the trip about once a week to Tel Aviv to teach RO technology to the staff at Mekorot (Israel Water Company).

The use of RO spread throughout the Arava and to Eilat. All of the drinking water of Eilat is today produced by RO. Mekorot operates more than 30 RO units for brackish water with a combined capacity of 40,000 m^3/d. Presently, plans are being made for a seawater RO plant near Ashdod with projected output of 180,000 m^3/d at a price of about 0.50 \$/m^3. This is down from 1.6 \$/m^3 ten years ago. A plant near Ashkelon is also planned with an output of 136,000 m^3/d.

Loeb is upset each time he sees commercial "spring" water sold in plastic bottles. Doing an off-the-cuff calculation, he tells me that the cost of that water is about 1,000 times more expensive than what it costs to make RO water, equal in all aspects.

Prof. Loeb's recent research has been focused in the area of pressure retarded osmosis (PRO) as a source of energy. This process is attractive in Israel due to the high osmotic pressure of Dead Sea brine. His aim is to use PRO to capture the available osmotic energy from Dead Sea brine when treated with brines of lower osmotic pressure, such as the Mediterranean Sea or Jordan River water. River water and seawater also comprise a vast, if difficult, osmotic pair for very large scale energy production.

Bob Weintraub
The Negev Academic College of Engineering,
Beer-sheva.